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Constructing digital economy index: Case of small open economy

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Abstract

The main objective of this study is to develop a Digital Economy Index (DEI) for the case of Malaysia. The procedure used in this study to construct a composite indicator was from the ideas proposed by the Conference Board. This composite DEI is constructed by the high correlation component series with the various methods and procedures proposed by the previous researchers. This study shows that the DEI has the leading power, leading the reference series (ICTE) on average for 2.8 quarters. Thus, DEI can be the short-term forecasting tool to decide due to it can provide an early signal than the ICTE for significant economic events. Therefore, the construction of DEI is significant as it can be used by policymakers to predict and measure the digital economy performance for the country.

Keywords: Digital Economy Index, composite indicator, forecasting
2020 MSC: 03H10

1 Introduction

The digital economy plays a prominent role in developing countries as drivers of innovation, competitiveness, and growth. It also contributes in other aspects such as creation of new opportunities for business through the invention of new products and services, supply platform and allocation to the markets, society well-being will increase and reduced the inequity, imbalance and the unfairness in the term of knowledge and information sharing, improvement to the environmental sustainability such as decreasing the fossil fuel emission via an increase of telework, smart public transport system and digital logistics. As a developing country in the Asia region, Malaysia had adopted digital technology in the economy as a catalyst to sustainable growth. Malaysia Digital Economy Corporation Sdn. Bhd. was established in 1996 to formulate and coordinate the agencies to enable successful development of the future proof workforce.

Figure 1 showed the data of the Information and Communication Technology (ICT) contribution to the Gross Domestic Product (GDP) from 1990 to 2018. The highest ICT contribution was recorded in 2011, which was US$3,067 million. However, the lowest ICT contribution to the GDP was recorded in the year 1998, which only US$153 million. It dramatically dropped of the amount of ICT contribution from the year 1997 to 1998, from US$1,508 million to US$153 million, approximately 89.85% decrease of the ICT contribution. This was due to the 1997 Asian Financial crisis that distorts the investors' confidence level and eventually decreases their investment. The digital economy for

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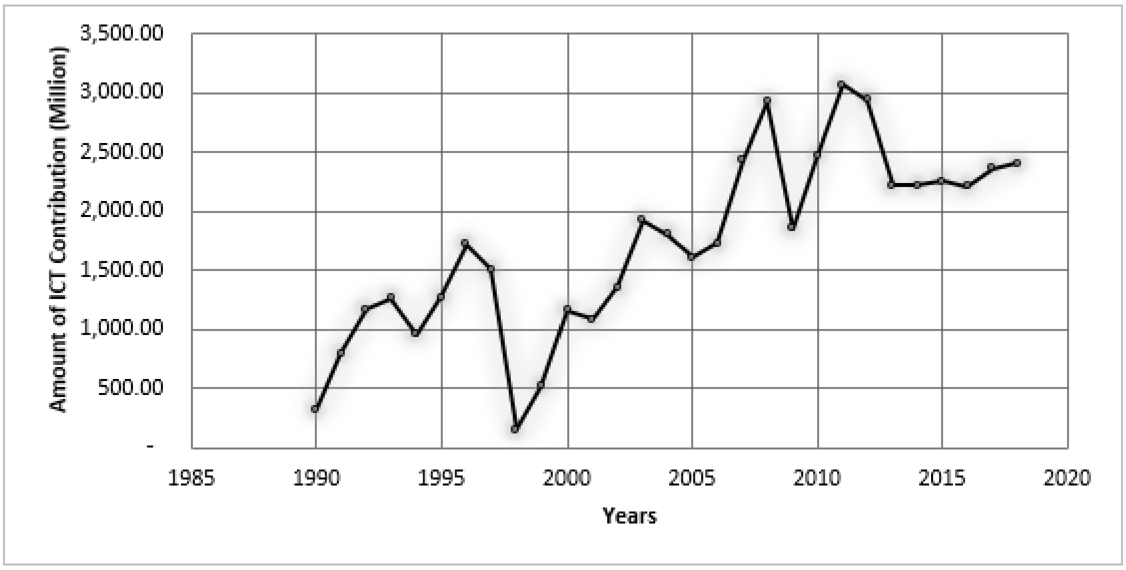

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Figure 1: Contribution of ICT to Gross Domestic Product (GDP) of Malaysia from 1990 to 2018

Malaysia on average has shown that value-added terms increase 9% per year from 2010 to 2016 [19]. Statistically, the growth of the digital economy is greater than GDP growth in Malaysia. This has highlighted the country's digital economy as a growing source of expansion. From this viewpoint, the digital economy has become an important source and leapfrog Malaysia achieves the Fourth Industrial Revolution that will be one of the forces that drive shared prosperity for all Malaysians.

This study aims to develop a Digital Economy Index (DEI) for the case of Malaysia to measure digital performance in Malaysia. This includes constructing a composite Digital Economy Index (DEI) in Malaysia, identifying the leading power of the constructed Digital Economy Index (DEI) in forecasting digital performance in Malaysia and examining the directional accuracy of the constructed Digital Economy Index (DEI) in forecasting digital performance in Malaysia.

This study contributes in the following aspects. First, there is no precise measurement for the digital economy based on the previous studies. Although the digital economy had contributed to the growth of the economy, the progress and improvement of the economic from the contribution of the digital economy remain uncertain. Second, most of the studies focused on a group of countries, either developed or developing countries, instead of a detailed study on a single country, such as Malaysia. Thus, this study is essential and serves as a reference for different stakeholders such as government and society. The government can forecast future trends in the future and adopt relevant policies to solve different economic problems. Apart from that, the digital economy index can also become a benchmark to the government to measure the improvement progress of the economy. Thus, the comprehensive digital economy index will serve as a forecasting tool for future trends.

This study is organized in the following sections. The first section will discuss the introduction, motivation and contribution of the study. The second section will discuss the previous studies, while the third section will highlight the index construction method and empirical models. The fourth section will present the result and analysis of the finding. Lastly, Section five will provide a conclusion and recommendation.

2 Literature Review

This section will present the previous research about the digital economy index and economic growth.[5]investigated the relationship between information technology and the productivity of 36 developing and developed countries from 1985 to 1993. Empirical findings indicated a positive relationship between information technology and growth in developed countries, however, the opposite impact can be observed in developing countries. [20] investigated the impact of telecommunications infrastructure on the economic growth of 113 countries from 1980 to 2000. The result for the study showed that telecommunications infrastructure and GDP had a positive causal relationship. Moreover, the telecom penetration rate for the countries was between 5 to 15 percent.

[12]investigated the effect of ICT on economic growth in the member countries of the Organization of the Petroleum Exporting Countries (OPEC) from 1990 to 2007 using the Generalized Method of Moments (GMM). The result showed

that there is a positive association between economic growth and ICT gross domestic investment. This implied that OPEC countries need to implement specific policies that facilitated the growth of the economy by the ICT investment. Besides that, [6] conducted a study on the ICT investment towards economic growth in Newly Industrialized Countries (NICs) in Asia with a sample time period from 1990 to 2007. The variables used in the study were divided into the ICT input and non-ICT inputs, where the physical capital, human capital and labor were considered as non-ICT input. Empirical findings indicated that ICT has a significant positive impact on the economic growth of the sample countries. [23] adopted decomposition analysis to examine the impact of ICT on the national economic structure of Indonesia from 1990 to 2005 and Japan from 1995 to 2005. The results showed that ICT has a significant impact on the economy of Japan. However, there is no significant impact in the case of Indonesia.

[17] examined the contribution of ICT investment on the economic growth of 26 industries in 18 Organisation for Economic Co-operation and Development (OECD) from 1995 to 2007 using Generalized Method of Moments (GMM). Empirical results indicated that ICT investment contributed 0.4% annually to value-added growth in the business. Furthermore, the computing equipment showed the largest contribution (50%) towards most OECD countries except Finland.

[15] examined the relationship between telecommunication infrastructure, gross capital formation and economic growth for G20 countries from the period of 1961 to 2012. The G20 countries were classified into two subgroups, which is developed countries and developing countries. Panel cointegration test and panel, Granger causality test, was adopted in the study to test and estimate the long run and causality relationships. The results indicated the existence of a positive association between ICT and investment on the economic growth of G20 countries. [14] studied the digital economy development level in Poland and selected European countries from years 2002-2016. Two indexes were used as the benchmark to measure the development of the E-economy were NRI (Networked Readiness Index) and DESI (Digital Economy and Society Index). The findings for this research showed that Poland had lower level of digital economy development as compared to other European countries.

Meanwhile, [16] had investigated how the broadband infrastructure affects the economic growth and employment of G20 countries using a panel data approach from 2001 to 2012. The outcome of the study indicated that economic growth in G20 countries would increase due to the ICT infrastructure. Meanwhile, [18] examined the association between the ICT infrastructure and the European Union (EU) economic growth from the year 2000 to the year 2017. Their results showed that there is a positive impact of ICT on the economic growth of EU members. Moreover, the magnitude of the impact was vary depending on the type of technology. [1] conducted a study on the relationship between the ICT and GDP growth in the developing countries of Middle East and North Africa (MENA) region and Sub-Saharan Africa (SSA) region. There are 45 developing countries used in the sample and data used covered 2007 to 2016. The result indicated that the ICT except fixed telephone contributed to the positive economic growth in selected developing countries. [13] studied the causal relationship between GDP and telecommunications from 1963 to 2015 in Algeria. Empirical findings showed two unidirectional causal relationships: fixed telephone to GDP and causal direction from the mobile phone to GDP.

3 Methodology

3.1 Data Description

There were more than 20 series of data will be collected from different sources such as World Bank, Department of Statistics Malaysia (DOSM), CEIC database and Malaysian Communications and Multimedia Commission (MCMC). The sample period for the database is 10 years from year 2009 to 2018. The data was collected and measured by the period of quarterly and yearly.

First of all, the theoretical framework was selected as the reference to build the DEI. Next, the reference series and component series will be chosen based on their characteristic with the good leading indicators. The data use for the study was retrieved from reliable sources and sample time period was 10 years from 2009 to year 2018. The last part to construct the DEI was applied based on [3] to build the index. Firstly, the Christiano Fitzgerald (CF) was used to smooth the inconsistent parameter for the detrending procedure. Next, the BBQ technique that proposed by [11] will be used to date the turning points and determine the critical episodes of digital economic in Malaysia. Then, the directional accuracy test was applied to investigate the performance of constructed DEI with the selected reference series. In short, the digital economy index was built from various quality indicators that can reflect the digital economy performance in Malaysia.

Based on Digital Economy Task Force (DETF)in Figure 2, member countries of G20 had developed a few goals to achieve the economy by the digital technology. The develop of digital economy such as use of knowledge and

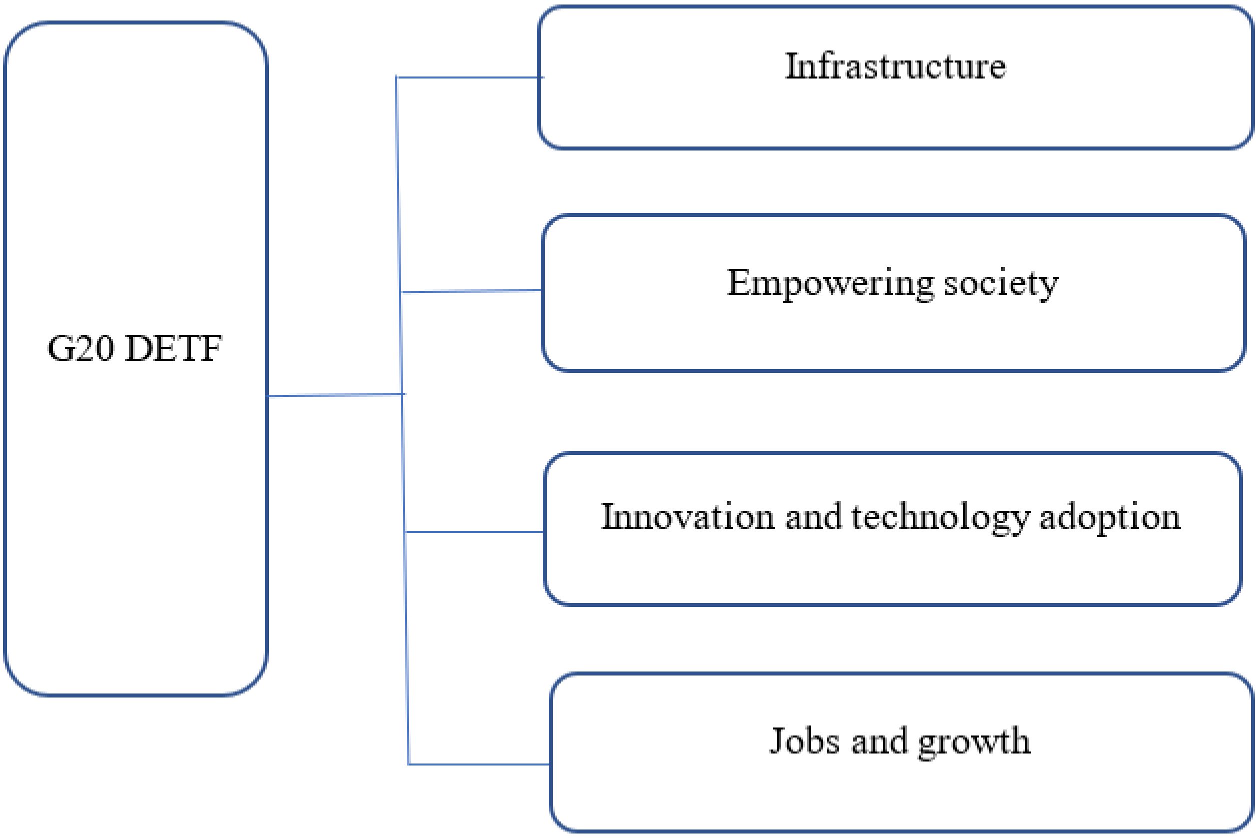

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Figure 2: Theoretical framework for G20 DETF

information, apply of information networks and innovation of information and communication technology (ICT) had given an impact to the growth of economy among the G20 countries.

In Table 1, there were four dimensions from this digital economy index framework and brings together 35 key existing indicators and methodologies in order to measure the digital economy. The first dimensions were infrastructure and measure by 8 indicators. This component was covered the indicators that involved in the development of physical, service and security of the infrastructure for the digital economy. Next, the empowering society is the second dimension for the index and measure by 7 indicators. This component focused on how the people use, access and interact by the digital technologies. Moreover, innovation and technology adoption also be an important component for this digital economy index. By this section, the indicators were used to identify and measure the innovation and development of digital technologies and how it contributed to the economy growth. The last dimension for the index is jobs and growth. The indicators under this component were focused on how the innovation and development of digital technologies contributed to the jobs market and the employment creation.

3.2 Digital Economy Index (DEI) Indicator Construction

To construct an indicator, a broad group of component series including the infrastructure, empowering society, innovation and technology, jobs and growth will be compiled. This is because to develop a leading indicator that reflects the digital economy for Malaysia, only the component series with the leading characteristics will be chosen. Then, the systematic compilation procedure that proposed by the [3] will be adopted to construct the DEI. The five-step procedure and formula were shown as below:

1. Month-to-month changes, $r_{i,t}$, is calculate for each component, $X_{i,t}$ where i = 1,. . . ,n. for the components that are in percent form, simple arithmetic differences are calculated:
$r_{i,t} = X_{i,t} - X_{i,t-1}$.

$$r_{i,t} = \frac{x_{i,t} - x_{i,t-1}}{x_{i,t} + x_{i,t-1}} * 200$$

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Table 1: List of Selected Component Series

	List of Component Series
INF	**Infrastructure**
FBSP	Fixed broadband subscriptions (people)
ES	**Empowering Society**
EPEM	Electronic Payment by E-money (RM billion)
PSGIRO	Payment Systems by Interbank GIRO (RM billion)
PCMB	Payment Channels by Mobile banking (RM billion)
NSMB	Number of Subscribers for Mobile Banking
MBPP	Mobile banking penetration rate to population (%)
MBPMS	Mobile banking penetration rate to mobile subscribers (%)
U	Internet usage
JG	**Jobs and Growth**
EICTT	Employee in ICT Trade ('000)
CSI	Computer, communications and other services (% of commercial service imports)
EICTM	Employee in ICT Manufacturing ('000)
PICTEX	ICT service exports (% of service exports)
ITA	**Innovation and Technology adoption**
RRD	Researchers in R&D: per Million people
PA	Patent applications

2. The month-to-month changes are adjusted by multiplying them with the component's standardization factor (w_i). The results of this step are the monthly contributions of each component
$c_{i,t} = w_i * r_{i,t}$.

3. The adjusted month-to-month changes are added (across the components for each month). This step results in the sum of the adjusted contributions,

$$S_t = \sum_{i=1}^{n} c_{i,t}$$

4. The preliminary levels of the index are computed recursively using the symmetry percent changes. It is calculated by letting the initial value for the first quarter, $I_1 = 100$ and the following month to be:

$$I_2 = \frac{200+\ S_2}{200-\ S_1} * I_1$$

5. Finally, rebase the base year of 2010 on the preliminary index.

3.3 Selection of Reference Series

The reference series to be chosen must be a long time and uninterrupted series as well it has a strong correlation to the digital economic growth [22]. Thus, the chosen reference series must indicate a trend of economy in the digital world and reflect the situation for the particular country. Normally, the ICT variables will be represented as the reference series which included the internet, cell phone, computer, fixed broadband, mobile broadband and intranet. For this study, the contribution of ICT to the national economy (ICTE) will be chosen as one of the best measurement tools to reflect the trend of economy affect by the digital world. All the series collected annually will be interpolated by using the [9] interpolation method into its quarterly basics.

3.4 Detrending Procedure

This method is used to identify the cyclical patterns in a particular data set. A detrend procedure is purpose to remove the effects of accumulating data sets from a trend and showed only the absolute changes and identifies the cyclical patterns. The filter used in this study was Christiano-Fitzgerlas (CF) Filter. The Christiano-Fitzgerlas (CF) filter was a band pass filter developed by [4] that was built on same principles as the Baxter and King (BK) filter[2]. The de-trending will be formulated in this filter and the problem in the frequency domain will be smoothing. The CF filter is better than BK filter due to it can work well on a larger class of time series and converges in the long run to the optimal filter.

The Christiano-Fitzgerlas (CF) filter can be calculate as follows:

$$c_t = B_0 y_t + \ B_1 Y_{t+1} + .. + B_{T-1-t} y_{T-1} + \tilde{B}_{T-1} y_T + B_1 y_{t-1} + .. + \tilde{B}_{t-1} y_1$$

$$B_j = \frac{\sin(jb) \ - \sin(ja)}{\pi_j} \ , \ j \geq 1$$

$$B_0 = \frac{b-a}{\pi} \ , \ a = \frac{2\pi}{P_u} \ , \ b = \frac{2\pi}{P_1}$$

$$\tilde{B}_k = -\frac{1}{2} \ B_0 - \sum_{j=1}^{k-1} B_j$$

The parameter p_u and p_i are the cut off cycle length in month. The cycles longer than pi and shorter than p_u are preserved in the cyclical term c_r.

3.5 Turning Point Dating Procedures

Bry-Boscham Quarterly (BBQ) algorithm that proposed by [11] was used to identify the turning points of the business cycle start from the steps of deseasonalized, detrending and smoothing the reference series. This BBQ algorithm test was used to determine the critical episodes of the business cycle. In order to translates the ocular judgements, there are three steps needed to perform:
1) Determination of possible turning points which is the peaks and troughs in a series.
2) A procedure for alternating peaks and troughs.
3) A set of rules that re-combine the turning points established after steps one and two in order to satisfy predetermined criteria concerning the duration and amplitudes of phases and complete cycles.

The core step of the algorithm to determine for the local peak or trough as happening at time t is shown as:
$\{a_{t-n} < a_t > a_{t+n}\}$, n =1, . . . , N
$\{b_{t-n} > b_t < b_{t+n}\}$, n =1, . . . , N

From this equation, a_t is the peak, b_t is the trough and n are generally set to five. The phase must last at least six months and the complete cycle should have the minimum duration of fifteen months. For the data that measures at the quarterly frequency, the first step of the BB algorithm should put n = 2 while a_t is a local maximum relative to two quarters.

$\{\Delta_2 a_t > 0, \ \Delta_{a_t} > 0, \ \Delta_{a_{t-1}} < 0, \ \Delta_2 a_{t+2} < 0\}$

3.6 Directional Accuracy Test

This test is the formal statistical approach to analysis the predictive accuracy of the indicator is particularly meaningful for a more credible study in the field of forecasting. From a forecasting perspective, renewed interest in direction accuracy of macroeconomics forecasts clearly indicates that unreliable forecast will make no sense to the users. Thus, if forecasting model comprises predicted changes that are not adequately significant to reflect the underlying impact of the real shock, then the forecasting result will be susceptible. According to [10], the indicators will be subjected to directional accuracy testing and complemented the findings with binomial testing. The cyclical change will break into three trichotomous scenarios; specifically, a large predicted increase, no significant change and a large predicted decrease. The directional accuracy rate is calculated by the formula below:

Directional Accuracy Result (DAR)=$\frac{C_s}{N_s}$ x 100

In addition, the binomial test with the directional accuracy result will be applied to know that whether the success of the prediction is owing to the predictive power of the forecasting model (indicator) or to mere chance. The verification is important to portray that the indicator itself has compelling predictive power and is robust over time. The null hypothesis of binomial test is the probability of correct prediction to direction of change in the forecasting model is 50 percent. The rejection for the null hypothesis will lead to two distinct conclusions, depending on the result of direction accuracy testing (DAR). If the DAR is over 50 percent, then show that the forecasting model is independent of wild guess. However, if the DAR is below 50 percent, then we can expect that wild guess possibly dominates the source for obtaining correct predictions. The failure in beating the wild guess again implies that the indicator is less likely to be robust forecasting tool.

3.7 Cubic Spline Interpolation

This method can use to estimating the quarterly series from the annual data. A piecewise seamless curve is obtained, and it passes through each of the observations of the underlying series over the sample period. From this method, there are not require any observed from higher-frequency indicator variable related to low-frequency series and it fits a series. Thus, this procedure correlates each of the data points efficiently and effectively even the data may appear randomly. The data is show as follow: S(y) = $\begin{cases} s_1(y), & if\ y_1 \le y < y_2 \\ s_2(y), & if\ y_2 \le y < y_3 \\ s_{n-1}(y), & if\ y_{n-1} \le y < y_n \end{cases}$

In order to define the S(y) splines, total 4(n) parameters had to be estimated, as there are n evenly spaced intervals and four coefficients are required for each interval. These coefficients twist the curve to let it pass through each of the observations without any interruption. This indicate that the curve does not show any breaks in continuity. $S_i(y)$ serve as a third-degree polynomial function and defined by,

$$S_i(y) = \beta_{3i}(y-y_i)^3 + \beta_{2i}(y-y_i)^2 + \beta_{1i}(y-y_i)^1 + \beta_{0i} \quad \text{for } y \in [y_i\ ,\ y_{i+1}]$$

where x_i can be obtained from the equation above. These conditions produce a piecewise continuous function, indicating that each of sub-functions must joint at the data point at both ends of the interval. To making the curve seamless and smooth across the interval points it required to impose the assumption of the continuity of the first and second derivatives:

$$S'_{i-1}(y_i) = S'_{i-1}(y_i),\ S''_{i-1}(y_i) = S''_{i-1}(y_i)\ \forall\ i = 1, 2, \ldots,\ n-1$$

4 Empirical Findings and Interpretation

To measure the digital economy performance in Malaysia, Department of Statistics Malaysia (DOSM) had taken an initiative to measure it by using satellite accounts approach through ICTE compilation. Therefore, the contribution of ICT to the economy (ICTE) of Malaysia is selected as the references series from year 2009 to 2018 in this study. The coverage of ICTE is consisting of the ICT sector which based on recommendation from OECD Guide to Measuring Information Society 2011 [7] and e-commerce by the OECD Internet Economy Outlook 2012 [8]. The ICTE has a more complete measure in most ICT sectors such as ICT manufacturing industry, ICT trade industry, ICT services industry and e-commerce which included the value added of wholesale and retail sectors. Thus, it is most suitable and acceptable to choose ICTE as the reference series of this study.

The data of ICTE are obtain in the yearly basis from year 2009 to 2018. After we complete collect the ICTE data, then the interpolation technique from [9] will be applied to interpolate the yearly ICTE series into its quarterly basis. All the ICTE data are calculated in the unit of RM billion and shown in the Figure 3 from the period of 2009 Q1 to 2018 Q4 by applied of interpolation techniques to the data. Based on the Figure 4, there are significant increase in the trend of ICTE from year 2009:Q1 to 2018:Q4 especially the increase significantly in year 2010. The launched of Economic Transformation Program (ETP) on 21 September 2010 had given a positive sign to the digital economy. By this programme, the government had focus to stimulate the creativity of human with new technologies and create more opportunity. Thus, there are more jobs opportunity and transform the nation into information and knowledge age. The limited of data transparency due to the license and rights protection by the laws had hold the growth of digital economy in the year 2013. Thus, this barrier has restricted the growth of the digital entrepreneurship especially those digital entrepreneurs who needs the open data in the development of mobile applications or other products.

However, the investment by the government in year 2014 had boosted the ICT sectors which included funding infrastructure expansion, providing support for both research and development (R&D), and private sector training. On the other hand, the slumped that captured in 2016 had indicated that lags in coverage and adoption of fixed broadband services, especially compared the level of economic development in Malaysia and the global.

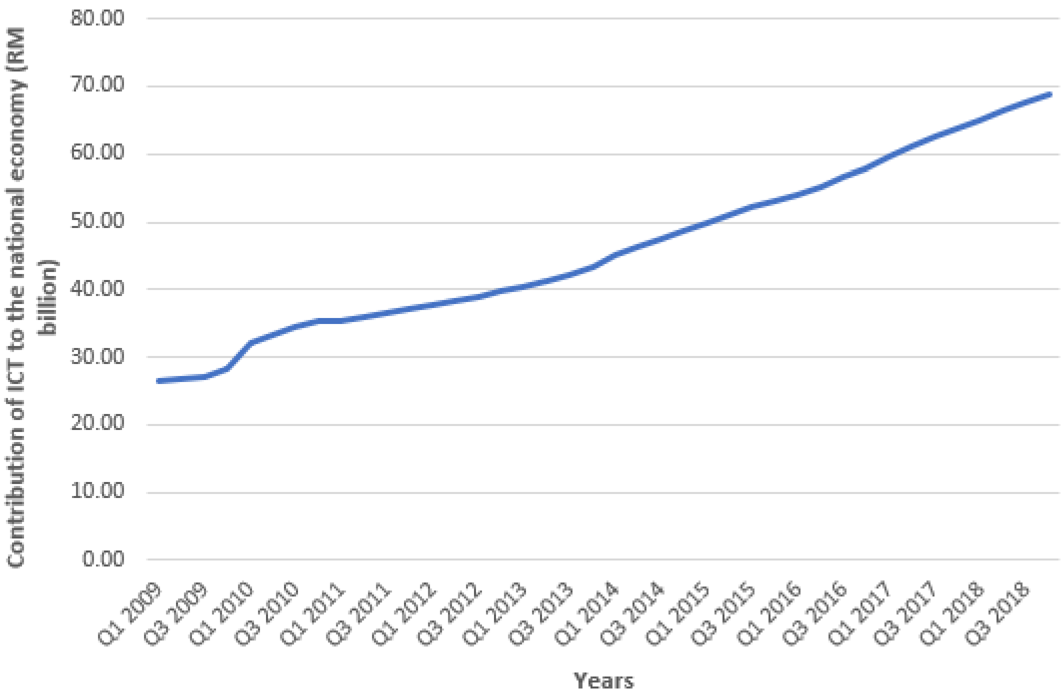

Figure 3: Contribution of ICT to the National Economy (ICTE)

To construct a good indicator in this study, the component series that showing leading characteristics will be chosen to build the DEI. All the selected component series must fulfil those criteria such as result in conformity, consistent timing and economic significance. Thus, there was more than 20 series of data were obtained from different sources which include CEIC database, World Bank, Department of Statistics Malaysia and ITU. Next, all the collected data will be compiled and examined the degree of association between reference series and selected component series by the correlation analysis.

Then, the correlation analysis will be used to test the compiled data that we gathered, and the results are show in Table 2. For this study, the component series will only choose by showing the strong correlation with our reference series. We are only choosing the component series that had the value of greater than 0.5 which are usually referred as positive and strong correlation. In contrast, any component series that had the value lower than 0.5 will be automatic eliminated and rejected as they may not bring the significant impact to construct a good leading indicator.

Based on the Table 2, the results show that the list of components that had the high correlation with the reference series and each them are category into the respective pillar. There are four pillars formed by respective component series which is Infrastructure (INF), Empowering Society (ES), Jobs and Growth (JG), Innovation and Technology adoption (ITA). By the development of digital technology, the basic digital infrastructure had play an important role to maintain the stable connectivity. According to the Internet User Survey (IUS) by the MCMC in year 2018, there are showing the increase of people connect to the internet by using the smartphone which is from 89.4% in year 2016 to 93.1% in year 2017. Thus, the subscription for various devices to the internet such as cellular and fixed telephone line are important and able to give a significant impact to the digital economy. Therefore, the fixed broadband subscription had category in this pillar.

Besides that, the empowering society also been chosen as one of the pillars because of the perception of people to use the internet can give the impact to the digital economy. By the advance of technology, there are increase of people willing to replace the traditional platform by the convenient way. One of the good examples is people are preferring to use the online banking services compare to physical present in the bank. By access the internet, various tasks such as online banking and payment can be complete within the short time and save cost. Therefore, the internet usage, electronic payment by E-money, payment systems by Interbank GIRO, payment channels by mobile banking, number of subscribers for mobile banking, mobile banking penetration rate to population and mobile banking penetration rate to mobile subscribers were category in this pillar.

On top of that, pillar of jobs and growth are represented by employee in ICT manufacturing, percentage of commercial services imports, percentage of ICT service exports and employee in ICT trade. The adoption of e-commerce and ICT technology in the business can also break the barrier to trade from each other. As the result of stable connectivity and penetration of internet, Malaysia had recorded a high rate of e-Commerce usage. There are recorded 16.53 million online shoppers and involve 62 percent of mobile users in year 2018 by the MCMC report. Nowadays, people are preferring to make the online shopping because of the price advantage and available of shipping. Thus, the increase of e-Commerce usage by various sector will give the huge impact to the trend of digital economy.

Table 2: Results of Correlation Analysis between Selected Component Series and the ICTE

INF		ES		JG		ITA	
FBSP	0.55	EPEM	0.98	EICTT	0.96	RRD	0.98
		MBPMS	0.98	CSI	0.69	PA	0.76
		MBPP	0.98	EICTM	0.60		
		NSMB	0.98	PICTEX	0.66		
		PSGIRO	0.98				
		PCMB	0.84				
		U	0.86				

The DEI are built by the selected component series which is aggregated into the composite form by the Conference Board method [3]. There are five chronological steps that mentioned in the previous chapter will be applied to the selected component series which included the procedure of aggregation. Hence, the computed DEI is shown in Figure 4 and Figure 5. From the Figure 6, it demonstrated that the DEI increase significantly and depicts the upward trend from the period of 2009 Q1 to 2018 Q4. However, there are few declines of the trend which happened in year 2013 and 2016 are due to the impact of limited data transparency and lags in digital infrastructure.

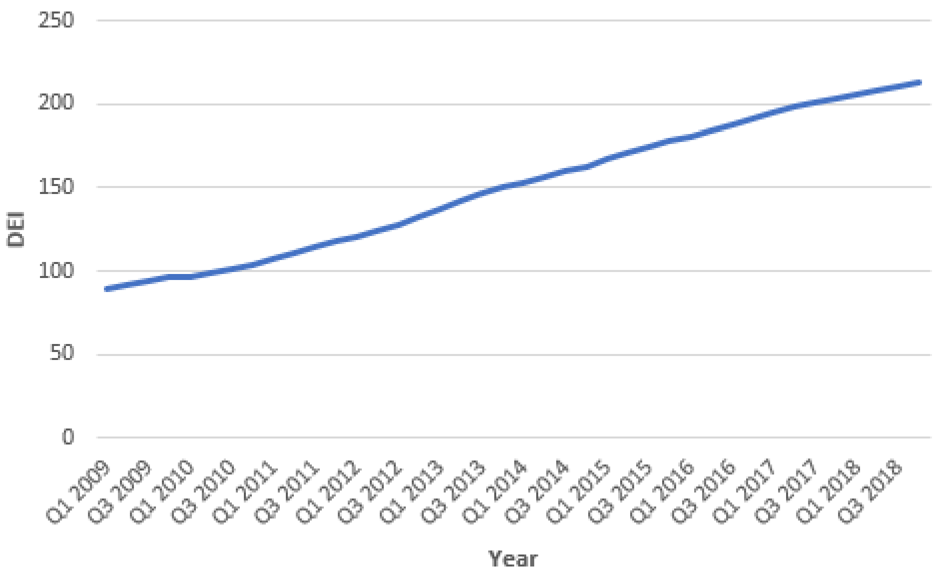

Figure 4: Digital Economy Index (DEI)

There are few method and techniques that proposed by [21] had been done and the result of cyclical movement of the ICTE and DEI has been shown in Figure 6. All of the steps were included detrending, smoothing and detecting the turning points of both DEI and references series.

The first method had been done before detecting the turning point is detrending procedure. In order to identify the cyclical patterns in a particular data set, detrending is important to remove the effects of accumulating data sets

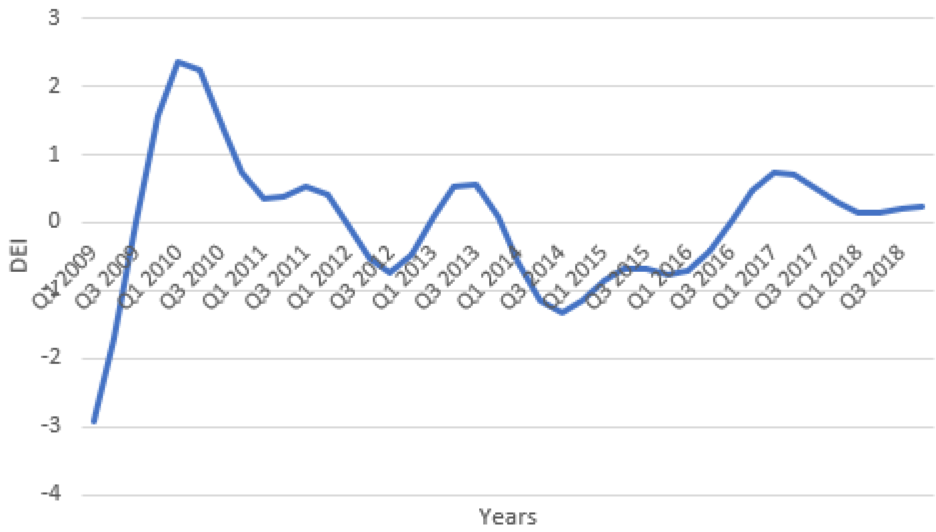

Figure 5: Cyclical Movement of Digital Economy Index (DEI)

from a trend and only show the absolute changes to identifies the cyclical patterns. For this study, the CF filter that proposed by [4] had been applied to measure detrend and cycle extraction. By this CF filter, the problem of variation can be reduced and smoothing the trend component. Therefore, the cyclical movement of the ICTE and DEI can be analysed and visualised after smoothened of both series.

From the Figure 6, there are few economic precariousness can be observed which happened in year 2010, 2013, 2014 and 2016. In year 2010, there are one economic program named Economic Transformation Program (ETP) had implement by government to help Malaysia to achieve high-income nation by 2020. From this program, one of the focus is sector information and communications technology (ICT) which can stimulate and boost the digital economy growth. The target of the government in this program is to transform the nation into the digital and knowledgeable by encourage more innovation on the product and boost up the competitive level in the global. As ICT became the key factor in digital economy, government also give the investment allowance for broadband service and remove the import duty and sale tax of broadband as the initiative to boost the digital economy.

In the year 2013, the formulation of Personal Data Protection Act (PDPA) had cause the ongoing tensions between data protection and its legitimate use for commercial purposes. Thus, the limitation of open data had become the barrier for the digital development especially the digital entrepreneurs which need it in the development of mobile applications or other products. Besides, the difficult to access government data also cause the lagging in Big data analytics. This is because most of the datasets on the portal do not specify a data license and government always reserve the rights for the datasets that hosted on agency websites. Thus, the lacked capacity and freedom to engage with the data especially the private sector will leave the potential digital entrepreneurs without the social connections, guideline and role model they need to succeed.

On the other hand, the increase of expenditure by government that focus to strengthen the ICT sector had given the influenced to boost the digital economy in year 2014. All of this expenditure included funding infrastructure expansion and support in research and development (R&D). The allocated of RM 2.7 billion for the construction of 1000 telecommunications towers and the laying undersea cables had speed up the connectivity and coverage. Besides the infrastructure spending, the allocated of RM 200 million to development of digital content and RM 1.3 billion in development of innovative and commercially viable technology by the government also give a great impact to the growth of digital economy. In addition, the allocated of RM 80 million to promote the use of new technology, automation and innovation by small and medium-sized enterprises (SMEs) also available to encourage more sector involve in digital economy.

However, the slumped of the trend that indicated in year 2016 had showed that Malaysia still lags in digital infrastructure. Although there are nearly 80 percent of the population has connected to the network, but the country still lags in the coverage and adoption of fixed broadband services when compare to its level of economic development. This is because there were only 9 fixed broadband subscriptions per 100 inhabitants in 2016 which less than the prediction. Furthermore, Malaysia also recorded as one of the countries that has slow download speeds and high prices.

This is because the domination Telekom Malaysia (TM) had controls 92 percent of fixed broadband subscriptions and cause the Malaysia's fixed broadband market are concentrated and lack of market competition. Therefore, the lags in digital infrastructure and domination of market will affected the digital economy in Malaysia.

Generally, Figure 6 had showed the result of cyclical movement for ICTE and DEI. By this Figure 6, the observation can be recorded that constructed DEI is moving ahead of ICTE in most of the time which it means that the turning point of DEI is leading a few quarter ahead as compare to the turning point of the ICTE. Hence, we can indicate that there are 4 turning points of digital economy index from the period 2009 Q1 to 2018 Q4. However, these 4 of the turning points are only the observation depicts from the graph. Thus, we need to applied the BBQ technique that proposed by [11] to date the turning points more accurately in this period and the result of the dating turning points will be discussed in the next section.

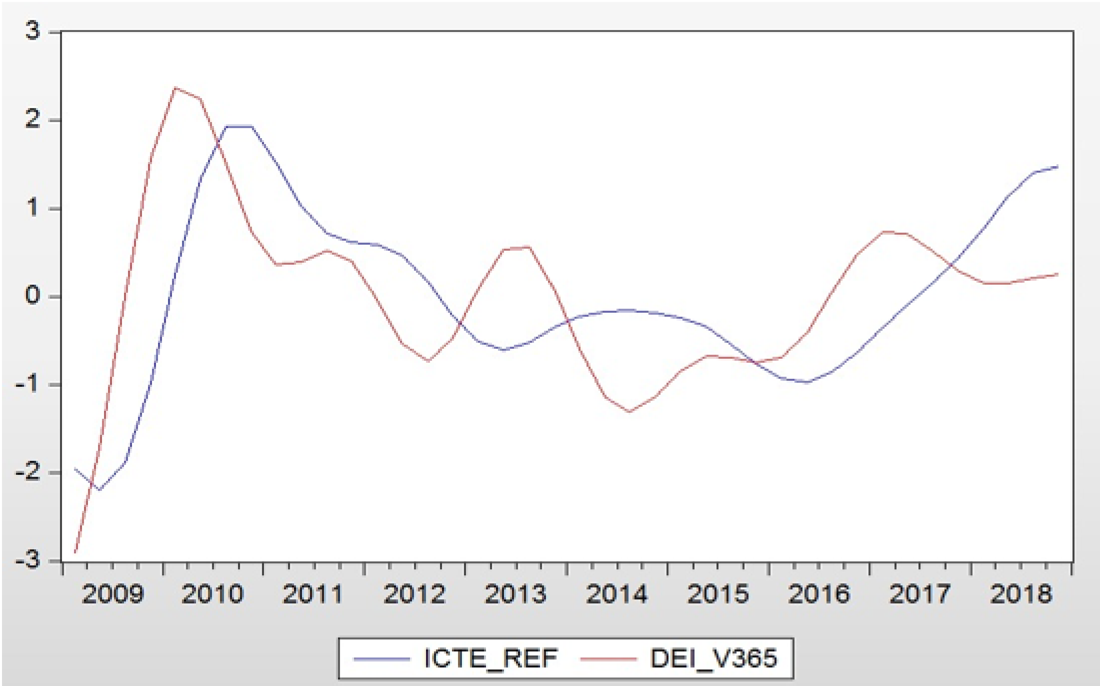

Figure 6: ICTE versus DEI (2009Q1-2018Q4)

By using the Bry and Boschan Quarterly (BBQ) technique that proposed by [11], we can identify the turning points of the reference series and DEI and presented it in the Table 4. All the quarterly basis data of the references series and DEI were obtained from the period of 2009 quarter 1 until 2018 quarter 4. From this Table 4, there are 3 peaks and 3 troughs presented for digital economy in Malaysia from the year 2009 to 2018. Although there are not all the peaks and troughs points of DEI leading the references series consistently, but the DEI are able to capture all the significant event in Malaysia and lead averagely 2.8 quarter which presented in the Table 4.

From the Table 4, all the significant events had been presented and all of them had discussed in the previous section. The first peak that happened in year 2010 was influenced by the launched of Economic Transformation Program (ETP) while the first trough was affected by the limited data transparency and data protection laws in year 2013. Besides that, the big portion of expenditure allocation for ICT sector and R&D had boost the digital economy and caused the second peak in year 2014. However, the problem of lags in digital infrastructure had exists the second trough which occurred in year 2016. In addition, this constructed DEI can capture the additional peak and trough for the year 2017 and 2018 respectively which there are undetectable by the ICTE. For the year 2017, the launch of Digital Free Trade Zone (DFTZ) had given the positive sign to improve the growth of digital economy while there are rise of cybercrime cases and cause the trough to happen in year 2018.

In short, the constructed DEI can capture and forecast all the short-term digital economic significant events in Malaysia. This DEI are constructed by 14 component which included fixed broadband subscription (FBSP), internet usage (U), electronic payment by E-money (EPEM), payment systems by Interbank GIRO (PSGIRO), payment channels by mobile banking (PCMB), number of subscribers for mobile banking (NSMB), mobile banking penetration rate to population (MBPP), mobile banking penetration rate to mobile subscribers (MBPMS), employee in ICT manufacturing (EICTM), percentage of commercial services imports (CSI), percentage of ICT service exports (PICTEX), employee in ICT trade (EICTT), number of researchers (RRD) and patent applications (PA).

Table 2: Result of Turning Point Analysis (CF Filter)

	ICTE	DEI	Amount of Lead/Lag (quarterly)	Important Events
Peak	2010 quarter 3	2010 quarter 1	+2	Economic Transformation Program (ETP)
Trough	2013 quarter 2	2012 quarter 3	+3	
Peak	2014 quarter 3	2013 quarter 3	+4	Expansion on ICT Expenditure
Trough	2016 quarter 2	2015 quarter 4	+2	
Peak	-	2017 quarter 1	-	Launch of Digital Free Trade Zone (DFTZ)
Trough	-	2018 quarter 2	-	Rise of Cybercrime
Amount of Lead/Lag (quarterly)			**+2.8**	

In this section, the directional accuracy test is applied to predicting the directional of the digital economy performance in Malaysia. The results of the directional accuracy analysis between the reference series ICTE and the constructed DEI are shown in Table 3. The purpose of this test is to identify whether the DEI can be the dependable estimating indicator to outperforming capability against the ICTE. The null hypothesis of the ICTE is that the estimating indicator is a dependable estimating indicator.

Based on the result, it is shown that the first 4 lags are exceeding 70% which presents that the DEI has more than 70% probability to make a prediction of the directional change. Next, the DAR also indicates that there are more than 60% for the fifth lag and 50% for the sixth lag for the DEI to predict the directional change. For the binomial testing results, it is shown that the binomial value is smaller than the 1% from the first lag to the third lag while smaller than 5% for the fifth lag and 10% for the sixth lag. Thus, the results show that we do not reject the null hypothesis for all the six lags because their binomial value are less than 1%, 5% and 10% significant level respectively. Therefore, it can be said that DEI can be the good estimating indicator for the digital economy in Malaysia.

Table 3: Result of Directional Accuracy and Binomial Testing

Lag (Quarter)	**Directional Accuracy Rate (%)**	**P(Binomial)**
1	74.36%	0.001***
2	78.95%	0.000***
3	78.38%	0.000***
4	72.22%	0.004***
5	65.71%	0.024**
6	58.82%	0.081*

5 Conclusion

The purpose of this study is constructing an indicator that can use to predict and forecast for the digital economy in Malaysia. In this study, the DEI was constructed by the procedure that proposed by the Conference Board [3]. The data of component series was collected from the various sources such as Department of Statistic Malaysia (DOSM), World Bank and CEIC from the period year 2009 to 2018. Besides that, the ICTE is selected as the reference series as it can capture most of the digital economy activity from ICT sector and e-commerce in Malaysia. Both the reference series and component series were transformed from the yearly basis data into the quarterly basis data by the method of interpolation from [9]. After that, the correlation analysis had applied to all component series and only those high correlation component series towards the reference series will be selected for this study.

The procedure that proposed by [21] was used to detect the cyclical movement of both ICTE and DEI which consist of detrending, smoothing and detecting the turning points. The first step was applied the CF filter that proposed by [4] for detrending and cycle extraction. Then, the Bry and Boschan Quarterly (BBQ) technique that proposed by [11] were used to date the turning points of both reference series and DEI. In addition, the directional accuracy test was applied to predicting the directional change of the digital economy performance in Malaysia. As the result, we can indicate that there were 3 peaks and 3 troughs presented and the computed DEI can lead the reference series on average of 2.8 quarter. In short, we can conclude that the developed DEI had the function to indicate the significant economic events happened and it can give the early signal than the reference series. Therefore, this DEI was very useful to reduce the economic precariousness in the short-term for the future in Malaysia.

5.1 Policy Implications and Recommendations

The past of ten years, there are various research had been done on the constructing the digital economy indicator for both developed and developing countries. However, there is only few researches on develop the digital economy index for the case of Malaysia. Hence, the DEI in this study are very useful to give the awareness to the policymakers to make the short-term forecasting and implement the suitable policy. By applying this DEI, the policymakers can forecast the short-term economy precariousness and against the economic uncertainty. Therefore, the DEI can act as a short-term forecasting tool for the investors and policymakers to make the effectively policy and avoid the unpredictable risk.

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